Appendix 4

Terrestrial Ecosystems Scoping Workshop Summary

TERRESTRIAL ECOSYSTEMS MONITORING SCOPING WORKSHOP
Arctic Network, National Park Service

April 26–28, 2005

Fairbanks, Alaska–Westmark Hotel

Purpose of the Workshop

The purpose of this workshop is to provide a forum for NPS resource managers and scientists to discuss ideas for building a statistically sound, ecologically based, management-relevant, and affordable monitoring program for the Arctic Network (ARCN) of parks. The information gleaned from this Terrestrial Ecosystems Workshop will be used to form the basis for drafting a long-term monitoring plan for the Arctic Network. All sections of this notebook are in draft form and will be revised after input from participants is received.

Objectives for the Scoping Workshop

1. Create conceptual ecosystem models and determine general monitoring framework
2. Develop working groups' highest priority candidate questions for terrestrial ecosystem monitoring
3. Identify potential attributes ("vital signs") for highest priority monitoring questions

Preliminary Agenda

Tuesday, 26 April

Objectives for Day One

1. Gain familiarity with ARCN monitoring goals
2. Overview of terrestrial ecosystems of Arctic Network
3. Overview of the workshop

12:00 WELCOME LUNCH

1:00 Welcome: Dave Mills, Tom Heinlein (Park Superintendents)

Introductions

Review of Agenda and Workshop Process: April Crosby, Meeting Facilitator

2:00 Overview of the NPS Inventory and Monitoring Program and the Arctic Network: Diane Sanzone, Arctic Network Coordinator

2:30 Additional Thoughts/Comments/Questions about the National Program Goals: Sara Wesser, Regional Coordinator

3:00 BREAK

3:20 Terrestrial Overview of Arctic Network Parks (10 min. each):

- Vegetation Ecology in the Arctic Network: Peter Neitlich
- Fire History and Burn Severity in the Arctic Network: Jennifer Allen
- Charismatic Megafauna of the Arctic Network: Jim Lawler
- Birds of the Arctic Network: Nikki Guldager
- The Big Why?: Integrating ARCN with NPS Park Management: Lois Dalle-Molle and Brad Shults
- Science for Wilderness and Wilderness for Science: Steve Ulvi

4:30 Presentations by Guests (20 minutes each with questions)

- Circumpolar Arctic Vegetation Map: Application for a Plant-Community-Level map of Arctic Alaska: Skip Walker
- Vegetation change following a 1977 tundra fire on Nimrod Hill, BELA: Chuck Racine
- The Role of Alder in Ecosystem Function and Landscape Evolution in Boreal and Arctic Alaska: Implications for Climate Change: Roger Ruess

5:30 Social hour with hot hors d' oeuvres and poster viewing

Wednesday, 27 April

Objectives for Day Two

1. Gain familiarity with terrestrial ecosystems of the Arctic
2. Create conceptual models for terrestrial-influenced ecosystems

8:00 Arrival and Continental Breakfast

8:30 Continuing Presentations by Guests (20 minutes each with questions)
- Monitoring bird populations and predicting effects of anthropogenic change in the Arctic National Wildlife Refuge: David Payer
- Using remote sensing to assess large scale habitat quality for ungulates: Brad Griffith
- Top down effects of large mammals on ecosystems: Dave Klein
- A Changing Arctic: The Past and Possible Future: Marc Stieglitz
- Contributions of Local Communities to Ecosystem Monitoring: Gary Kofinas

10:10 BREAK

10:30 Continuing Presentations by Guests (20 minutes each with questions)
- North Slope Development: Harry Bader
- Arctic Contaminates: Linda Hasselbach (by phone)

11:10 Conceptual Models from previous workshops: Torre Jorgenson

11:40 Draft Terrestrial Conceptual Models: Diane Sanzone

12:00 Overall sample design for monitoring (an example from SWAN): Bill Thompson

12:30 LUNCH

1:30 Reconvene Together for Instructions to Working Groups for Day

1:45 Working Groups: Each working group will revise the draft conceptual ecosystem models. Each group can revise the model(s) as much or as little as they see fit. Creation of additional ecosystem models is encouraged. A leader for each group must report back to the larger group on revised or new model(s). Laptops, large sheets of paper, and overhead copies of the models will be available for this purpose.

3:45 BREAK

4:00 Reports from working groups on revised conceptual ecosystem models (15 minutes per group, with questions)

5:00 RECESS

6:00 Meet at Pike's for dinner. Host: Jim Lawler

Thursday, 28 April

Objectives for Day Three

1. Identify potential monitoring questions for terrestrial-influenced ecosystems
2. Develop list of priority monitoring questions for terrestrial-influenced ecosystems
3. Identify possible attributes ("vital signs") for monitoring terrestrial-influenced ecosystems

8:00	Arrival and Continental Breakfast
8:30	Review Agenda and Instructions to Working Groups: April Crosby and Scott Miller
8:45	Working Groups: Each working group will develop a comprehensive list of potential monitoring questions, organized by sections on the electronic worksheet provided. A recorder for each group must type the questions into the worksheet on the laptop, and a working group member must be prepared to review questions with the whole group.
10:45	BREAK
11:15	Reports from working groups on potential monitoring questions for each ecosystem (15 minutes for each group, with questions)
12:15	Large Group Discussion: Are we missing anything?
12:30	LUNCH
1:30	Reconvene in Working Groups: Develop from the list of monitoring questions the five highest priority candidates for monitoring and an exhaustive list of potential "vital signs" for each of them.
2:30	BREAK
2:50	Reports from working groups on priority monitoring questions and a list of potential vital signs (15 minutes for each group, with questions)
3:50	Large Group Discussion: The whole group will identify the highest priority monitoring questions and possible "vital signs" for monitoring.
4:50	Final and summary thoughts from workshop participants for Diane and the Technical Committee as they go forward in designing the monitoring program.
5:15	Adjourn

Tentative Participant List

Ken Adkisson
Western Arctic National Parklands
National Park Service
PO Box 220
Nome, AK 99762
Phone: 907-443-6104
Fax: 907-443-6139
ken_adkisson@nps.gov

Jennifer Allen
Yukon Charley Rivers/
Gates of the Arctic National Park and Preserves
National Park Service
201 First Ave
Fairbanks, AK 99701
Phone: 907-455-0652
Fax: 907-455-0601
jennifer_allen@nps.gov

Stephen M. Arthur
Division of Wildlife Conservation
Alaska Department of Fish and Game
1300 College Road
Fairbanks, AK 99701
Phone: 907-459-7336
Fax: 907-452-6410
steve_arthur@fishgame.state.ak.us

Harry R. Bader
Division of Land
Alaska Department of Natural Resources
3700 Airport Way
Fairbanks, AK 99709
Phone: 907-451-2740
Fax: 907-451-2751
harry_bader@dnr.state.ak.us

Andrew W. Balser
Institute of Arctic Biology
University of Alaska Fairbanks
PO Box 757000
Fairbanks, AK 99775-7000
Phone: 907-474-2466
Fax: 907-474-6184
fnawb@uaf.edu

Brian M. Barnes
Institute of Arctic Biology
University of Alaska Fairbanks
PO Box 757000
Fairbanks, AK 99775-7000
Phone: 907-474-6067
Fax: 907-474-6967
ffbmb@uaf.edu

Syndonia Bret-Harte
Institute of Arctic Biology
University of Alaska Fairbanks
PO Box 757000
Fairbanks, AK 99775-7000
Phone: 907-474-5434
Fax: 907-474-6967
ffmsb@uaf.edu

Catherine F. Cahill
Geophysical Institute
University of Alaska Fairbanks
PO Box 756160
Fairbanks, AK 99775-6160
Phone: 907-474-6905
Fax: 907-474-5640
ffcfc@uaf.edu

Lois Dalle-Molle
Alaska Cooperative Ecosystem Studies Unit
National Park Service
201 First Ave
Fairbanks, AK 99701
Phone: 907-457-99701
Fax: 907-455-0601
lois_dalle-molle@nps.gov

Brad Griffith
Alaska Cooperative Fish and Wildlife Research Unit
University of Alaska Fairbanks
PO Box 757020
Fairbanks, AK 99775
Phone: 907-474-5067
Fax: 907-474-6716
ffdbg@uaf.edu

Lynn Griffiths
National Park Service
240 West Fifth Avenue, Room 114
Anchorage, AK 99501
Phone: 907-644-3573
Fax: 907-644-3806
lynn_griffiths@nps.gov

Thomas Hamilton
Branch of Alaskan Geology
U.S. Geological Survey
4200 University Drive
Anchorage, AK 99508-4667
Phone: 907-786-7451
Fax: 907-786-7401
thamilto@usgs.gov

Tom Heinlein
Bering Land Bridge National Preserve
National Park Service
PO Box 220
Nome, AK 99762
Phone: 907-443-6101
Fax: 907-443-6139
thomas_heinlein@nps.gov

Kyle C. Joly
Northern Field Office
Bureau of Land Management
1150 University Avenue
Fairbanks, AK 99709
Phone: 907-474-2203
kyle_joly@ak.blm.gov

Torre Jorgenson
ABR Inc.
PO Box 80410
Fairbanks, AK 99708
Phone: 907-455-6777
Fax: 907-455-6781
tjorgenson@abrinc.com

Knut Kielland
Institute of Arctic Biology
University of Alaska Fairbanks
PO Box 757000
Fairbanks, AK 99775-7000
Phone: 907-474-7164
Fax: 907-474-6967
ffkk@uaf.edu

David R. Klein
Institute of Arctic Biology
University of Alaska Fairbanks
PO Box 757020
Fairbanks, AK 99775-7020
Phone: 907-474-6674
Fax: 907-474-6967
ffdrk@uaf.edu

Gary Kofinas
Institute of Arctic Biology
University of Alaska Fairbanks
PO Box 757000
Fairbanks, AK 99775-7000
Phone: 907-474-7078
Fax: 907-474-6967
ffgpk@uaf.edu

Amy Larsen
Yukon Charley Rivers/
Gates of the Arctic National Park and Preserves
National Park Service
201 First Avenue
Fairbanks, AK 99701
Phone: 907-455-0622
Fax: 907-455-0601
amy_larsen@nps.gov

Jim Lawler
Yukon Charley Rivers/
Gates of the Arctic National Park and Preserves
National Park Service
201 First Avenue
Fairbanks, AK 99701
Phone: 907-455-0624
Fax: 907-455-0601
jim_lawler@nps.gov

Thomas J. Liebscher
Yukon Charley Rivers/
Gates of the Arctic National Park and Preserves
201 First Avenue
Fairbanks, AK 99701
Phone: 907-455-0620
Fax: 907-455-0601
thomas_liebscher@nps.gov

Michael R. Lilly
GW Scientific
PO Box 81538
Fairbanks, AK 99708
Phone: 907-479-8891
Fax: 907-479-8893
mlilly@gwscientific.com

William F. Manley
Institute of Arctic and Alpine Research
University of Colorado
Campus Box 450
Boulder, CO 80309-0450
Phone: 303-735-1300
Fax: 303-492-6388
william.manley@colorado.edu

Paul E. Matheus
Alaska Quaternary Center, UA Museum
University of Alaska Fairbanks
PO Box 756960
Fairbanks, AK 99775
Phone: 907-474-2688
Fax: 907-474-5469
ffpem1@uaf.edu

Chris McKee
Yukon Charley Rivers/
Gates of the Arctic National Park and Preserves
National Park Service
201 First Avenue
Fairbanks, AK 99701
Phone: 907-455-0636
Fax: 907-455-0601
chris_mcKee@partner.nps.gov

Scott D. Miller
Arctic Network
National Park Service
201 First Avenue
Fairbanks, AK 99701
Phone: 907-455-0664
Fax: 907-455-0601
scott_miller@nps.gov

Dave Mills
Yukon Charley Rivers/
Gates of the Arctic National Park and Preserves
National Park Service
201 First Avenue
Fairbanks, AK 99701
Phone: 907-457-5752
Fax: 907-455-0601
dave_mills@nps.gov

Peter Neitlich
Western Arctic National Parklands
National Park Service
41A Wandling Rd
Winthrop, WA 98862
Phone: 509-996-3203
Fax: 509-996-8031
peter_neitlich@nps.gov

Link Olson
University of Alaska Museum
University of Alaska Fairbanks
PO Box 756960
Fairbanks, AK 99775-6960
Phone: 907-474-5998
Fax: 907-474-5469
link.olson@uaf.edu

David Payer
Arctic National Wildlife Refuge
U.S. Fish and Wildlife Service
101 - 12th Avenue, Room 236 Box 20
Fairbanks, AK 99701
Phone: 907-455-1830
Fax: 907-456-0428
david_payer@fws.gov

Brian T. Person
Department of Wildlife Management
North Slope Borough
PO Box 69
Barrow, AK 99723
Phone: 907-852-0350
Fax: 907-852-0351
brian.person@north-slope.org

Richard A. Ring
Department of Biology
University of Victoria
PO Box 3020
Victoria, BC V8W 3N5
Canada
Phone: 250-721-7102
Fax: 250-721-7120
raring@uvic.ca

Roger W. Ruess
Institute of Arctic Biology
University of Alaska Fairbanks
PO Box 757000
Fairbanks, AK 99775-7000
Phone: 907-474-7153
Fax: 907-474-6967
ffrwr@uaf.edu

Diane M. Sanzone
Arctic Network
National Park Service
201 First Ave
Fairbanks, AK 99701
Phone: 907-455-0626
Fax: 907-455-0601
diane_sanzone@nps.gov

Susan Sharbaugh
Alaska Bird Observatory
PO Box 80505
Fairbanks, AK 99708-0505
Phone: 907-451-7159
Fax: 907-451-7079
ssharbaugh@alaskabird.org

Enoch Shiedt, Sr.
Maniilaq Association
PO Box 256
Kotzebue, AK 99752
Phone: 907-442-7678
Fax: 907-442-7678
eshiedt@maniilaq.org

Brad Shults
Western Arctic National Parklands
National Park Service
201 First Avenue
Fairbanks, AK 99701
Phone: 907-455-0674
Fax: 907-455-0601
brad_shults@nps.gov

Marc Stieglitz
School of Civil and Environmental Engineering
Georgia Institute of Technology
790 Atlantic Avenue
Atlanta, GA 30332-0355
Phone: 404-385-6530
Fax: 404-385-1131
marc.stieglitz@ce.gatech.edu

Robert Stottlemyer
U.S. Geological Survey
240 West Prospect Road
Fort Collins, CO 80526
Phone: 970-498-1017
Fax: 970-498-1010
robert_stottlemyer@usgs.gov

William Thompson
Lake Clark National Park & Preserve
National Park Service
240 W. Fifth Avenue
Anchorage, AK 99501
Phone: 907-644-3685
Fax: 907-644-3809
bill_thompson@nps.gov

Jason Vogel, Ph.D.
University of Florida
Department of Botany
220 Bartram Hall
Gainesville, Fl 32611
Phone: 352-392-9620
Fax: 352-392-3993
jvogel@ufl.edu

Donald (Skip) A. Walker
Institute of Arctic Biology
University of Alaska Fairbanks
PO Box 757000
Fairbanks, AK 99775-7000
Phone: 907-474-2460
Fax: 907-474-2459
ffdaw@uaf.edu

Sara Wesser
Alaska Region
National Park Service
240 W Fifth Avenue
Anchorage, AK 99501
Phone: 907-644-3558
Fax: 907-644-3806
sara_wesser@nps.gov

Steven B. Young
Center for Northern Studies
479 Cross Road
Wolcott, VT 05680-4088
Phone: 802-888-4331
Fax: 802-888-3969
sbyoung@pshift.com

Terrestrial Ecosystem Scoping Workshop

Participant List by Working Group

Group 1 Biogeochemistry	Group 2 Biodiversity	Group 3 Landcover/Land Change	Group 4 Migratory and Invasive Species
Bob Stottlemeyer	Brian Barnes	Skip Walker	Brad Griffith
Brian Person	Jason Vogel	Andrew Balser	Dave Payer
Cathy Cahill	Dave Klein	Bill Manley	Enoch Shiedt
Knut Kielland	Kyle Joly	Harry Bader	Paul Matheus
Marc Stieglitz	Link Olson	Michael Lilly	Steve Arthur
Roger Ruess	Richard Ring	Tom Hamilton	Steve Machida
Syndonia Bret-Harte	Susan Sharbaugh	Torre Jorgenson	Ken Adkisson
Vlad Romanovsky	Sara Wesser	Lynn Griffiths	Brad Shults
Tom Heinlein	Bill Thompson	Steve Young	Tom Liebscher
April Crosby (facilitation)	Gary Kofinas	Jennifer Allen (facilitation)	Jim Lawler (facilitation)
Amy Larsen (database)	Peter Neitlich (facilitation)	Scott Miller (database)	Chris McKee (database)
	Lois Dalle-Molle (database)		

Terrestrial Ecosystems of ARCN

The ARCN parks contain a broad array of the ecosystems typical of the subarctic (boreal forest or taiga), and arctic (tundra) biomes of northwestern North America. The boundary, or ecotone between these two biomes is also represented in many different phases. Because these parks encompass large areas of mountainous terrain, including a major portion of the Brooks Range, they also include examples of virtually every type of alpine situation to be found in northern Alaska.

The nature of boreal and arctic ecosystems is often profoundly influenced by climate, especially whether and to what degree the climate is maritime or continental. The climate of the ARCN parks varies from the extreme continentality of interior Alaska to the more maritime coastal areas of the parks bordering the Chukchi Sea. This maritime climate is, however, somewhat modified by the presence of pack ice, which minimizes the moderating effect of the sea during the six to nine months it is present. Thus winters, even in coastal areas, are intensely cold and have relatively moderate precipitation and snow cover.

Overview of Terrestrial Vegetation

As is discussed in the following section, the most conspicuous feature of the vegetation in northwestern Alaska is the treeline, or northward or coastward limit of conifer forest. The forest reaches its northwesternmost limit in North America in the vicinity of the eastern border of Cape Krusenstern and the western edge of the Noatak Preserve (Young 1974) but treeline forms a complex and convoluted boundary through much of the three more eastern parks. A number of other organisms have ranges strongly associated with the presence of conifers: red squirrels, porcupines, certain typically understory plants, some tree-nesting birds, and some epiphytic lichens are examples. Overall, though, the presence or absence of conifer forest has relatively little effect on the composition of the vegetation and, especially, the flora (Young 1989).

Vascular Plants

Western and northwestern Alaska has long been recognized as having the richest array of vascular plants of any region in the circumpolar north (Hulten 1937, 1968). This is due to a number of factors, the most important of which are as follows. First, the area was never totally glaciated during the later Pleistocene. This means that populations of many species of plants were presumably able to survive *in situ* throughout the period that most of the rest of northern North America was repeatedly glaciated (Hopkins et al. 1982). It also means that soil formation and various geological processes that result in stable substrates have been going on uninterrupted for very long times in comparison to other North American areas, which have often been scoured to bare rock within the past 10,000 to 12,000 years. A second important factor is the location of the area at a place where many of the major mountain ranges of the world converge. The Brooks Range extends thousands of kilometers southward into North America, while similar connected mountain ranges extend deep into central Asia. Thus, the Beringian region has probably long served as a "staging area" for alpine plants that are slowly colonizing the Arctic (Young 1971). Finally, the complex local topography and history of local glacial advance and retreat have created great variety in local habitats in terms of substrate, soils, microclimates, and disturbance.

There is currently little agreement or understanding of the responses of vascular plant vegetation to changing conditions, although this field is developing rapidly (Bradley 1999). Treeline and its advances

and possible retreats has been an area of major interest since the mid-20th century, but the processes that influence the spread or retraction of the ranges of conifers are complex enough, and long-term enough, that the documentation and interpretation of changing treeline is still in its early stages. Much recent research deals with changes in the nutrient regimes and the stability of various tundra plant communities, and this line of investigation is very promising in terms of developing a theoretical framework and set of protocols for monitoring tundra ecosystems and interpreting their response to changing environmental factors (Chapin et al. 2000, Mack et al. 2004).

In terms of local areas of rare or unusual species and communities of vascular plants, there are many examples known and undoubtedly many more to be discovered. An example would be the extensive serpentine barrens in the vicinity of Feniak Lake, in the middle Noatak Drainage. This area actually contains a great variety of sub-sites with their individual and unique array of plants. It is, of course, important to identify and protect these unusual situations, but their usefulness in determining the overall health of the environment is not entirely clear.

Nonvascular Plants

Lichens and bryophytes are a conspicuous and ecologically important element in Alaska's arctic parks. Nonvascular plants are likely to represent 75 to 80% of ARCN's flora (Neitlich and Hasselbach 1998, NPFlora 1989). In many cover types, these plants constitute a co-dominant portion of the biomass (Viereck et al. 1992, Swanson et al. 1985) and account for a significant amount of cover in NPS's satellite imagery-based landcover maps (Markon and Wesser 1997, Markon and Wesser 1998, Swanson et al. 1985) and vegetation classifications (TNC 1999, Viereck et al. 1992). Because of their fragility, ecological importance as forage, and high sensitivity to impacts from pollution (Pegau 1968, Nash1988), the inventory and monitoring of lichens and bryophytes is a priority statewide.

Key among the ecological roles of Alaskan arctic lichens and bryophytes are forage, nesting materials or direct shelter, nitrogen fixation, and primary productivity. Lichens serve as a major food source for many small and large mammals, including muskoxen, Dall's sheep, and ground squirrels (Sharnoff and Rosentreter 1998). An adult caribou typically consumes 5–6 kg/day of lichens during winter (Boertje 1984). Lichen consumers represent a major prey base for several top predators (e.g., wolves, bears, and owls). Lichens represent an exclusive food source for large numbers of arthropods (Gerson 1973), and contribute a small but significant quantity of fixed nitrogen to the region's nutrient-poor, low-productivity ecosystems (Gunther 1989).

Lichens are extremely fragile, slow-growing, and sensitive to air pollution (Richardson 1992). Different lichen species grow between 0.1 mm to about 5 mm per year. Because of slow growth and poor dispersal ability by lichens, attainment of late-successional terrestrial or epiphytic lichen communities can take up to 250 years in boreal and arctic environments (Black and Bliss 1978, Christiansen 1988). Lichens rely entirely on atmospheric inputs of water and nutrients for growth and have evolved to uptake atmospheric inputs readily without barriers of specialized tissue. Because of this, they are extremely susceptible to injury by sulphur and nitrogen-based pollutants and acidification (Richardson 1992, McCune 1988). For this same reason, they are also reliable as passive monitors of contaminant accumulation via elemental analysis of tissue (Ford and Vlasova 1996).

Birds of the Arctic Network

Most birds found in the ARCN are summer nesters or migrants, with only about a dozen species overwintering within the network. There is evidence supporting the presence of a total of 177 bird species in the Arctic Network, with individual parks containing between 114 and 132 species (Appendix 2), and as many as 12 to 26 species that have yet to be documented in one or more of the parks (NPSpecies 2004). A certified species list with citations will be available in the fall of 2005, following the completion of final reports of the bird inventory efforts and the quality assurance/quality control process for the NPSpecies database.

Prior to current efforts, the ARCN was largely unsurveyed, leaving a gap in our knowledge of the breeding distribution and habitat requirements of many migrant and resident bird species. Fieldwork for a three-year montane-nesting bird inventory of the network was completed in 2003, with data analysis and final report compilation occurring in 2005. In addition, I&M and the Park Flight Program recently provided support for bird inventories within GAAR for a three-year land bird inventory scheduled for completion in 2005.

The northwest Alaska region provides important bird habitat because it is a major breeding area for migratory birds from as far away as Antarctica. This region encompasses a zone of interchange between the flyways of Asia and North America, and it includes important transitional habitat areas between boreal forest, coastal lands, and tundra.

More than 25 species of waterfowl inhabit the network's wetland areas. All four loon species are found in the Noatak drainage. The lagoons between Cape Krusenstern and Sheshalik are heavily used by migrating waterbirds. This area is also an important subsistence hunting area for waterfowl and as an egg gathering area. It is an important fall staging area for thousands of geese, ducks, shorebirds, and gulls. Prime waterfowl nesting areas also occur in the extensive wet lowlands in the Kobuk valley. In BELA and CAKR, the marine/estuarine habitat, together with extensive freshwater ponds and lakes, provides resting, nesting, feeding, and molting grounds for large populations of migrating geese, ducks, and shorebirds. The salty grasslands and marshes at the mouths of the Nugnugaluktuk, Pish, and Goodhope rivers and Cape Espenberg are especially important for waterfowl adapted to estuarine conditions.

Raptors find important habitat within the Noatak drainage. Thirteen species of raptors are known in the preserve, and GAAR provides montane nesting habitat for numerous species with breeding ranges limited to Alaska, such as the surfbird and Smith's longspur (Tibbitts et al. 2003).

Of special interest among the remaining birdlife are several Asian species that have extended their ranges into North America along the Bering Land Bridge corridor. These include the wheatear, yellow wagtail, white wagtail, bluethroat, and arctic warbler (Young 1974).

Mammals of the Arctic Network

Approximately 42 species of terrestrial mammals are believed to occur within the boundaries of the Arctic Network park units, ranging in size from the tiny shrew (*Sorex yukonicus*) to brown bears (*Ursus arctos*) and moose (*Alces alces*). A certified species list with citations will be a vailable in fall 2005, following the

completion of final reports of the mammal inventory efforts and the quality assurance/quality control process for the NPSpecies database.

Many arctic mammal populations, such as lynx (*Lynx canadensis*), snowshoe hare (*Lepus americanus*), caribou (*Rangifer tarandus*), and lemmings (*Dicrostonyx* spp. and *Lemmus* spp.), are characterized by local, seasonal, or cyclic abundance. Distribution and abundance data are almost nonexistent except for animals hunted for subsistence.

Distributions of arctic mammals are changing within historic times, such as the expansion of moose into the western Brooks Range within the last 70 years (Coady 1980) and the extirpation of muskoxen in the mid 19th century and their subsequent reintroduction during the 1970s (Lent 1999). Other species that have recently expanded their ranges north and west into one or more of the arctic park units include beaver and coyotes. Other large changes in populations include the 50 to 70% decline in the GAAR sheep population in the late 1980s, the 70% decline in moose on the drainages on the north side of the Brooks Range in the early 1990s, and the six-fold increase in the Western Arctic caribou herd during the last 25 years (75,000 animals in 1976 to 450,000 in 1999).

Ecological and distributional information about arctic mammals is scant compared to that of parks in the contiguous U.S., where small changes in species' ranges are being tracked at a fine scale as species move north and up in altitude, in a possible response to global climate change (Burns et al. 2003).

Recent I&M field inventories have demonstrated the paucity of knowledge of even the presence of the few species in the Arctic by providing vouchers for 12 mammal species not previously documented in one or more of the ARCN parks. By park unit, the number of new mammal species documented during inventory fieldwork from 2001–2003 were five in GAAR, two in NOAT, eight in KOVA, four in BELA, and six in CAKR. Additional literature searches have located more obscure documentation of an additional 10 species that were not previously thought present in one or more of the ARCN parks. Overall, recent efforts have increased the number of mammal species known to be present in each of the ARCN parks by 19.

Some of the more notable species documented for the first time in one or more of the parks include the tiny shrew (*Sorex yukonicus*) which was newly discovered in GAAR, KOVA, BELA, and CAKR; the pygmy shrew (*S. hoyi*) newly documented in KOVA and CAKR, resulting in a known range extension of approximately 250 kilometers; the barren ground shrew (*S. ugyunak*) discovered in GAAR, BELA, CAKR, and NOAT (previously only documented on the North Slope, these new vouchers resulted in a known range extension of 300 kilometers south); the taiga vole (*Microtus xanthognathus*), in KOVA and NOAT (new vouchers resulting in 150 kilometer range extension to the northwest); and the porcupine (*Erethizon dorsatum*) in GAAR, of which few vouchers exist anywhere in the Brooks Range.

Among documented species, large data gaps and issues remain. For example, very few vouchers exist for marmots in Alaska, especially in the Arctic, where it is thought there may be two separate species: the Alaskan marmot and hoary marmot (*Marmota broweri* and *M. caligata* respectively). Physical differences between these two species are so slight and understudied that no reliable published keys exist for identifying them. It is thought that the two species differ greatly in origin, with the Alaskan marmot being more closely related to Asian marmot species than to any North American marmot species (Olsen pers. comm.). A third species of marmot (*M. monax*), the woodchuck, has expanded its range from the

Lower 48 as far north as Fairbanks during recent decades. Additional arctic and subarctic species that are thought to occur in the park but for which no documentation exists include pika (*Ochotona collaris*), bats (*Myotis* spp.), and the tundra hare (*Lepus othus*). Species thought to be expanding their ranges to interior Alaska from Canada include mountain lions (*Felis concolor*) and mule deer (*Odocoileus hemionus*). Range information and monitoring is thought to be especially important for Alaskan species in light of the more dramatic climate changes predicted for the region and the "sky island" populations (as species ranges move up in altitude) that may result.

In addition to the terrestrial mammals, it is estimated that more than 13 species of marine mammals use the waters of the Chukchi Sea and Kotzebue Sound adjacent to Cape Krusenstern National Monument and Bering Land Bridge National Preserve. Both BELA and CAKR have mandates for the protection of marine mammal habitat (jurisdiction ends at the high-tide line). Polar bears and seals make dens or have haul-outs on the mainland, and many are frequently sighted in estuarine environments or small bays.

Records of Past Ecosystems and Events

The ARCN area contains exceptional opportunities for developing a picture of the events and processes that have resulted in the current array of ecosystems, both within the parks and preserves and in the circumpolar Arctic and boreal regions in general (c.f. Hopkins et al. 1982, Elias and Brigham-Grette 2000). The evidence ranges from large physical features such as moraines and beach ridges to long-term records of past environmental and climatic trends, such as sediment columns and animal fossils, to information derived from archaeological studies.

The importance of studies of this kind for our purposes is that they can establish a known trajectory for the direction and magnitude of ecosystem change and the processes that influence them over long periods of time. When information about the nature of the modern ecosystems and the processes occurring within them can be evaluated in relation to long-term environmental changes—or stability—this can greatly increase our ability to discern their significance.

The main reason for this unusual richness of potential paleoenvironmental data lies in the fact that much of the area was never glaciated during the Pleistocene and thus formed a part of unglaciated Beringia, as the eastern extension of the ancient Eurasian Arctic is often called. Other parts of ARCN were subject to only local glaciation, especially during the latter part of the Pleistocene. Additionally, some exceptional circumstances, such as the survival of ancient lake sediments at Immuruk Lake and the burial of ancient land surfaces under tephra, such as occurred on the northern Seward Peninsula, have created important opportunities for research.

The ARCN has been inhabited by humans for at least 12,000 to 13,000 years, and perhaps twice as long or even longer. There is abundant evidence for human activities for the past 4,000 to 5,000 years, and a major product of the study of these ancient cultures has been the accumulation of evidence for the nature of the environment in which these people lived. Archaeological studies are not only important in helping to document the role of prehistoric people in the local environment. They also often provide a rich source of data on aspects of the environment that are little affected by the presence of humans. For example, the spread of moose into northwestern Alaska in historic and late precontact times is largely known through the presence or absence of evidence for moose in well-documented archaeological sites throughout the area.

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ARCN Draft Monitoring Objectives for Terrestrial Ecosystems

Objective 1: Collect baseline data on the physical, chemical, and biological parameters of tundra and boreal forests within the Arctic Network of parklands.

Objective 2: Determine long-term trends in the physical, chemical, and biological characteristics of boreal and tundra ecosystems within the Arctic Network of Parklands.

Objective 3: Understand how landscape components interact at various spatial and temporal scales to affect terrestrial ecosystems.

Specific Monitoring Questions for Terrestrial Ecosystems of the Arctic Network

Numbers in red following questions from the database output indicate the overall ranking by the group. The number indicated the number of dots. Higher numbers indicate question was ranked higher; lack of number indicates no ranking.

I. Biodiversity Working Group

Question 1: How is climate change altering biodiversity within the parks? How are species distributions changing? (27)

Question 2: How is climate change altering biodiversity within the parks? How are plant communities changing in structure and distribution? (6)

Question 3: How is climate change altering biodiversity within the parks? How does timing/conditions during the growing season affect biodiversity? (17)

Question 4: How is biodiversity changed by human-caused perturbations in the parks? How do changes in patterns of human use of the parks affect habitat use by native species?

Question 5: How is biodiversity changed by human-caused perturbations in the parks? What is the effect of changes in access/use?

Question 6: How is biodiversity changed by human-caused perturbations in the parks? How do changes in fire regimes affect biodiversity?

Question 7: How is biodiversity changed by human-caused perturbations in the parks? How do airborne pollutants affect biodiversity? (11)

Question 8: How is biodiversity changed by human-caused perturbations in the parks? How does consumptive use or nonconsumptive use affect biodiversity?

Question 9: What changes in biodiversity will alter key ecosystem processes within the parks? What are key ecosystem processes? (6)

Attribute (Component/Process): nitrogen fixation (defoliators/herbivores…), Nutrient flow (hydraulics, carriers of marine derived nutrients), food web linkages (keystone species), primary productivity (biomass, plant cover), secondary productivity (megafauna, predators, herbivores, subsistence species, fish, birds, overwinter survival (winter refugia), migration corridors

Question 10: How do changes in habitat type, proportions, quality, and distribution affect biodiversity? How do changes in wetlands, alpine, and other environments affect biodiversity? (6)

II. Biogeochemistry Working Group

Question 1: What are the impacts of melting permafrost on nutrient cycling and element transport in the parks?

Attribute (Component/Process): ambient temperature, precipitation, snow cover, solar radiation, cloud cover, storm tracks, wind speed and direction, natural disasters, and spatial weather patterns

Potential Measures: soil temperature, active depth layer, map of permafrost distribution

Question 2: What are trajectories of climate change in ARCN parks?

Attribute (Component/Process): track ambient temperature, precipitation, snow cover, solar radiation, cloud cover, storm tracks, wind speed and direction, natural disasters, and spatial weather patterns

Potential Driver/Stressor of Change: greenhouse gases, human industry, aerosols

Potential Measures: weather stations, lightning strike data, deposition, and aerosol and gas measurements

Question 3: Are contaminant levels in terrestrial ecosystems of the Arctic Network changing?

Attribute (Component/Process): monitor contaminant loads (snow cover, soil organic matter, vegetation, invertebrates, birds, and mammals)

Question 4: Which biogeochemical cycles are most sensitive to changing biodiversity and associated shifts in community structure (e.g., relative abundance of functional groups)? Which type of organism found in the parks is most impacted by altered biogeochemical cycles? (18)

Attribute (Component/Process): track nutrient dynamics (nitrogen, carbon, and phosphorus) and identify species and/or functional groups that are impacted by change in nutrient status

Potential Measures: pools and fluxes of nitrogen (N), carbon (C), phosphorus (P), and sulphur (S) and measures of individual species and functional groups, restrict to vascular and nonvascular plants and animals

Question 5: Which interactions between, and traits of, species most impact biogeochemical cycling? How do invasive species and species loss effect biogeochemical cycling in the parks?

Attribute (Component/Process): identify current, and track changes in, species traits (e.g., growth form), ecosystem-level function (e.g., abundance and distribution), and interactions (e.g., plant-soil-herbivore interactions and associated alteration of C, N, P, and S fluxes)

Potential Driver/Stressor of Change: climate change, human development

Potential Measures: litter quality, tissue quality, growth rates, nitrogen fixation, net primary production (NPP), secondary production, element export

Question 6: In ARCN parks, what is the relative importance of physical vs. biological processes in regulation of biogeochemical cycling?

Attribute (Component/Process): track impacts of physical processes (permafrost freezing/thawing, thermokarsting, hydrology, radiation, cloudiness, landscape features) in relation to species composition

Question 7: How will long-term climate change affect reservoirs of soil carbon and impact large-scale nutrient dynamics within the Arctic Network?

Potential Driver/Stressor of Change: climate

Potential Measures: stocks and turnover of nutrients and C, NPP, δN^{15}, C^{14} (turnover), C^{13} paleo record potential here, common litter decomposition experiments

Question 8: In which ways does variation in short-term climate regime (e.g., seasonality) influence biogeochemical cycling?

Attribute (Component/Process): seasonal coupling of biological components with climate variability (e.g., seasonal vegetation quality, snow pack persistence, precipitation, timing and distribution of mammal migration, seasonal forage quality, key biogeochemical processes, species composition and abundance, plant community composition)

Potential Driver/Stressor of Change: climate change, seasonality

Potential Measures: seasonal vegetation quality (plant phenology), snow pack persistence, precipitation, timing and distribution of mammal migration, seasonal forage quality, key biogeochemical processes, species composition and abundance, plant community composition

Question 9: Can paleo-records of changes in element cycling inform us of current dynamics?

Attribute (Component/Process): paleorecords from lake cores as indicators of historical species (distribution, composition, and invasion), and ecosystem productivity)

Potential Driver/Stressor of Change: climate change, humans

Potential Measures: pollen, macro fossils, C/N content, elemental and isotopic contents

Question 10: In ARCN parks does human land and resource use ameliorate and/or perpetuate current trends and patterns of biogeochemical cycling?

Attribute (Component/Process): human impacts (e.g., industrial development, subsistence and recreational use) on key biogeochemical processes (hydrology, species density, aerosols)

Potential Driver/Stressor of Change: road development, pollution, hydrocarbon and metal exploration, trail use and expansion, hard rock mining, and extraction, human use patterns, harvest and access, road development, pollution, hydrocarbon and metal exploration, trail use and expansion, hard rock mining, access road development, pollution, hydrocarbon and metal exploration, trail use and expansion

Potential Measures: key biogeochemical processes, landscape hydrology, aerosol measurements

Question 11: What are the consequences of changing the balance of nutrient inputs (C, N, P, silicon [Si], iron [Fe], S)? Do increased inputs translate into accelerated cycling within ecosystems and changes in retention and export?

Attribute (Component/Process): key biogeochemical processes, changing inputs, element stocks and fluxes, aerosol measurements, N fixation, nutrient retention and export of key elements

Potential Driver/Stressor of Change: anthropogenic activity

Potential Measures: aerosol measurements, N fixation, nutrient retention and export of key elements

Question 12: How do inputs of trace metals, pollutants and organic matter interact with biogeochemical cycles?

Attribute (Component/Process): metal and POP concentrations in subsistence foods,elemental composition of human tissue or blood, organics as carriers bioaccumulation and transport, aerosol measurements, and gas phase measures, animal tissue, plants and lichen composition

Potential Driver/Stressor of Change: anthropogenic activity

Potential Measures: elemental composition of human tissue or blood, organics as indicators of bioaccumulation and transport, aerosol measurements, and gas phase measures, animal tissue, plants and lichen composition

Question 13: How do changes in terrestrial carbon storage and nutrient and sediment export influence aquatic ecosystems? (18)

Attribute (Component/Process): nutrient and carbon inputs/output into streams and lakes, output or loss

Potential Driver/Stressor of Change: water flow, permafrost melting, ATV trail use, water tracks, climate change

Potential Measures: dissolved organic carbon (DOC), dissolved organic nitrogen (DON), total dissolved solids (TDS), dissolved inorganic nitrogen (DIN), bacterial, aufwuchs, macroinvertebrates, guilds of grazers

Question 14: What are the key landscape features that control nutrient flux at multiple spatial and temporal scales?

III. Landcover/Landchange Working Group

Question 1: How are glaciers responding to climate change? (rapid response to climate change) (22)

Attribute (Component/Process): snowfall, glacier extent and area, thickness, surface elevation

Potential Driver/Stressor of Change: climate change

Potential Measures: aerial photography/imagery, comparison with radar, LIDAR, topographic maps, DEM's, mass balance

Potential Partners: Water Resources USGS, UAF-GI, GLIMS, INSTAAR

Question 2: How is climate change affecting the distribution and characteristics of ice patches? What are the archaeological & paleoecological materials and significance?

Attribute (Component/Process): size/area extent, exposed organic materials (basal debris zone yields perishable resources, macrofossils, dung)

Potential Driver/Stressor of Change: climate change, surface energy, looting

Potential Measures: inventory/size, how quickly melting out, emergency situation

Question 3: What is the depth, phenology, and distribution of snowpack? What are the controls (precipitation, wind, weather patterns, etc.)?

Attribute (Component/Process): snowpack, depth, aerial extent, distribution, phenology, hardness/structure of ice layers

Potential Measures: sensors, photodocumentation, satellite imagery, radar (temperature, moisture, slushiness), few climate stations

Question 4: What are the basic controls on climate and how are they changing?

Attribute (Component/Process): cloud cover, temperature, precipitation, active layer, basic components, storm tracks

Potential Measures: remote sensing, avhrr, remote weather stations

Potential Partners: USGS Gary Clow

Question 5: Are there spatial and temporal changes in permafrost? (Coastal)?

Attribute (Component/Process): depth to permafrost, susceptibility, surface topography/thermokarst/thermal erosion, soil temp, surface icings, changes to thaw lakes

Potential Driver/Stressor of Change: climate change, fire, human disturbance

Potential Measures: active layer thickness, lidar, survey transects, aerial, remote sensing

Question 6: What are the changes in frequency, distribution, and characteristics of rock glaciers, landslides, and debris flows?

Question 7: What is the distribution of vegetation across the landscape and how is it changing? (31)

Attribute (Component/Process): physiognomy, biomass, phenology, community assemblages and distribution, forest cover, alder cover, shrub height, lichen cover, species composition, community cover, riparian zones

Potential Measures: normalized difference vegetation index (NDVI), satellite imagery, stratify landscape (average, max NDVI), Max NDVI, plot sampling (ground truth), time-lapse camera, mapping plant communities, light detection and ranging (LIDAR)

Potential Partners: Native communities

Question 8: Where do we find rare habitats and plant communities and what are their controls?

Attribute (Component/Process): community composition, rare and unusual substrates, hot or warm springs, threatened habitats, occurrence/distribution of rare habitats

Potential Driver/Stressor of Change: climate change/human impacts, human use

Potential Measures: species composition/cover, bedrock/surficial geology, inventory locations, temperature, chemistry, discharge

Potential Partners: UAF, archeological community, USGS water, Native community, university researchers

Question 9: What is the fire regime and is it changing? (12)

Attribute (Component/Process): extent and area burned, timing of burn, frequency of burn, severity, landcover type, post-fire succession, fire suppression effects, exotics, fire management regimes, distribution and timing of lightning strikes

Question 10: How do plant communities differ between different bedrock types?

Attribute (Component/Process): substrate/bedrock, slope stability

Question 11: How is shore and bank erosion impacting archaeological sites?

Attribute (Component/Process): coastal bank recession

Potential Driver/Stressor of Change: global warming, sea level rise, anthropogenic effects

Question 12: How is changing landcover affecting the distribution and characteristics of water resources?

Attribute (Component/Process): Timing of breakup and freeze up, channel dynamics, wetlands, thermokarst, lake levels

Question 13: How are hydrologic regimes changing? Are streams and floodplain interactions changing?

Question 14: How are human activities modifying the landscape? (21)

Question 15: How is forest distribution changing?

Attribute (Component/Process): treeline; forest cover, density, and species composition; reproduction, herbivory and disease

Question 16: How does distribution of glacial deposits affect plant communities and how do they respond to change?

Attribute (Component/Process): surficial geology, soil parent material, landscape age, plant communities, soil development

Question 17: How will atmospheric contaminants affect plant community distribution and composition?

Attribute (Component/Process): sphagnum, metals, sulfates, nitrates, dust

Potential Driver/Stressor of Change: climate, anthropogenic activities

Question 18: What does the paleorecord reveal about previous change? How stable is the landscape? (26)

Attribute (Component/Process): pollen records, glacier fluctuation, macrofossils, sediment records, peat stratigraphy, bluff exposures, middens, unique paleontological resources, rates of change

Potential Driver/Stressor of Change: erosion, human activities (illegal collection)

Question 19: Is permafrost degrading today in response to changing climatic conditions? (19)

Potential Measures: depth to permafrost, active layer thickness, soil temperatures, permafrost temperature

Question 20: How are geomorphic processes changing the landscape? (15)

Potential Drivers/Stressors: floodplain development through channel change/flooding and sedimentation, slope instability, dust, dune activation/stabilization, retreat of glaciers altering stream hydrology/sedimentation

IV. Migratory and Invasive Species Working Group

Question 1: How is the composition and relative abundance of small mammals changing over time?

Attribute (Component/Process): small/meso mammal abundance, community composition

Potential Driver/Stressor of Change: climate change, predators, diseases and parasites, changes in vegetation

Potential Measures: trapping grids, burrow surveys, sighting surveys

Potential Partners: UA museum

Question 2: Is the timing of migration changing?

Attribute (Component/Process): migratory mammals, migratory birds

Potential Driver/Stressor of Change: climate, fire, development, condition of wintering grounds, changes in vegetation

Potential Measures: first arrival of caribou on calving grounds, calving ground departure, first arrival of nesting golden eagles

Potential Partners: ADF&G, industry, UAF, BLM, regional Native corporations, regional and local governments, USFWS

Question 3: Is the distribution of migratory species changing over time?

Attribute (Component/Process): migratory mammals, migratory birds

Potential Driver/Stressor of Change: climate, fire, development, condition of wintering grounds, changes in vegetation

Potential Measures: seasonal distribution location

Potential Partners: ADF&G, industry, UAF, BLM, regional Native corporations, regional and local governments, USFWS, international partners, NGO's

Question 4: Has the phenology of vegetation development changed?

Attribute (Component/Process): vegetation phenology

Potential Driver/Stressor of Change: climate

Potential Measures: timing of green-up and senescence, maximum biomass

Potential Partners: NASA, USGS, NOAA

Question 5: How has the composition of the vegetation changed?
Attribute (Component/Process): plant community composition
Potential Driver/Stressor of Change: climate, herbivory
Potential Measures: species presence or absence
Potential Partners: BLM, USFWS

Question 6: How is the abundance, distribution, and timing of migration changing? (19)
Attribute (Component/Process): species abundance and distribution
Potential Driver/Stressor of Change: various
Potential Measures: species-specific
Potential Partners: many

Question 7: How is the distribution of invasives changing? (5)
Attribute (Component/Process): species distribution and abundance
Potential Driver/Stressor of Change: various
Potential Measures: species specific
Potential Partners: many

Question 8: What is controlling the range expansion of key species? (18)
Attribute (Component/Process): muskox, moose, ravens, alder, coyotes, white spruce, beaver

Question 9: How is the availability of subsistence resources changing over time? (18)
Attribute (Component/Process): Dall's sheep, fish (pike, white fish, burbot), carnivores, berries, caribou, waterfowl, fur bearers, roots, black bear, ground squirrels

Additional Discussion Materials
Terrestrial Ecosystems Scoping Workshop
Day 1: Tuesday, 26 April 2005

Introductory Speakers

The workshop started with welcoming remarks by Dave Mills, superintendent at Yukon Charley and Gates of the Arctic Park and Preserve and representative from the Arctic Network (ARCN) Board of Directors. After introductions, April Crosby, workshop facilitator, reviewed the workshop objectives and agenda.

Diane Sanzone, ARCN Coordinator, provided an overview of the Inventory and Monitoring program (I&M) and specifically of the Arctic Network, within that program. The next speaker was Sara Wesser, regional coordinator of the I&M program. She emphasized that monitoring must be ecologically oriented as well as sustainable over time, while still flexible enough to incorporate future planning and budget scenarios. Participants should imagine what managers will want to know in future decades (20 to 50 years) when developing monitoring questions. She said that although program funds are not competitive, all proposals will be evaluated in terms of program strategic purposes. Sara then responded to questions, including one concerning the distinction between parks and preserves and another about coordination amongst networks. She gave an overview of coordination and collaboration amongst networks at all stages of program development and outlined the congressional requirement to use standard methodologies where possible. Recommendations from scoping meetings, for instance database use and certain methodologies, can be shared amongst networks and parks although each unique park requires specific treatments. She informed the audience that there are regular meetings among Alaska network staff members. Diane confirms that she has regularly relied on information provided by other networks.

- *Hamilton: quote from Richard Nelson, these parks are not "just wild lands but home lands" reminds us these are unique among parks*
- *Klein: beware of "fuzzy assumptions" about parks—the public view of parks is different from that of scientists, "healthy system" is not always a helpful term; there are numerous interpretations and definition of "invasive species" i.e., are humans an invasive species?*
- *Wesser: the distinction between natural and anthropogenic change is arbitrary and not always necessary.*

Overview of ARCN Parks

Six presentations providing an overview of the ARCN parks followed:

I. Peter Neitlich remarked on ARCN vegetation ecology. He noted that (1) the most up-to-date permafrost mapping is 20 years old, (2) successional trajectories for all vegetation types have been outlined, and (3) Norway lichen presence has decreased since 1973.

- *Stieglitz: is there evidence of the change projected by Hadley model (based on Bachelet's work)? [Neitlich: there is anecdotal evidence, but we have not been out there long enough.]*
- *Sanzone: we have no vegetation staff and need advice*
- *Young: suggest using old photography, with comparisons like Tape and Sturm*

II. Jennifer Allen gave a presentation on ARCN wildfire and effects. Presentation includes reference to Charles Racine's talk on the 1977 fire in BELA. The discussion following this included:

- *Question: how are you measuring fire severity? [Allen: using remote sensing, comparing reflectance in Landsat photos, assessing on the ground.]*
- *Bader: how does monitoring program take into account interagency fire management and corresponding varying suppression policies, e.g., the Seward Peninsula example? [Allen: preliminary review of average fire size in different fire management options indicate that average fire size has been reduced by fire suppression in full and critical suppression areas.]*
- *Barnes: is increased shrub cover related to climate change or fire? [Allen: probably both.]*

III. Jim Lawler presented overview of ARCN megafauna. He emphasized that little is known about mammals, even large species, in some of the remote areas.

- *Wesser: there are muskox only in CAKR and BELA—are other megafauna found across all parks?*
- *Lawler: no sheep in BELA or CAKR, a few muskox in GAAR and Kobuk*

IV. Nikki Guldager presented ARCN bird overview.

V. Lois Dalle-Molle and Brad Shults discussed ARCN park management issues.

VI. Steve Ulvi addressed NPS and ARCN wilderness issues.

Invited Expert Presentations

I. Skip Walker presents "Applying the Circumpolar Arctic Vegetation Map to Plant-Community-Level Maps of the Arctic." The following questions were asked:

- *Sanzone: can we extend your approach to the rest of the ARCN area? [Walker: yes, it is plausible, but need to begin with existing maps.]*
- *Manley: how did you define arctic? [Walker: basically by vegetation patterns.]*

II. Paul Matheus presented "The Paleohistory of Arctic Parks."

III. Roger Ruess presented "The Role of Alder in Ecosystem Function and Landscape Evolution in Boreal and Arctic Alaska: Implications for Climate Change."

IV. Cathy Cahill presented "Overview of Arctic Air Pollution."

Day 2: Wednesday, 27 April 2005

Invited Expert Presentations continued.

V. David Payer presented, "Monitoring Bird Populations and Predicting Effects of Anthropogenic Change in the Arctic Refuge."

VI. Brad Griffith presented "Using Remote Sensing to Assess Large-scale Habitat Quality for Ungulates."

VII. David Klein presented "Top-down Effects of Large Mammals on Ecosystems."

VIII. Marc Stieglitz presented "The Changing Arctic: Past and Possible Future.

IX. Gary Kofinas presented "Contributions of local Communities to Ecosystem Monitoring."

X. Harry Bader presented "North Slope Development." The following discussion ensued:

- *Klein: are mandates for DNR independent of other state agencies? [Bader: DNR is unique among state agencies as management— it is not regulatory, it is fee simple, and it sets conditions as proprietor. Only value in best interest of state is net revenue to state treasury—and this trumps other agencies' mandates on state land.]*
- *Sanzone: what are the top five threats from development to the parks? [Bader: seismic, seismic, seismic, road, off road: 3,600 sq. miles are authorized for seismic activity. Road from Happy Valley 80 miles west. DNR has been told to develop a plan for ORV management in the Dalton corridor.]*
- *Question: what about follow-up on monitoring impacts of development? [Bader: there is no institutional memory on previous development to see effects of decisions, for example, regarding gravel extraction. We are trying to start this.]*
- *Walker: people are not aware of the threat from seismic activity. [Bader: we have been trying to get the word out.]*

XI. Linda Hasselbach presented "Arctic Contaminants in the Red Dog Mine Corridor" by phone.

- *Payer: what's the expected lifespan of mine? [Hasselbach: About 50 years, though other deposits in area may be developed.]*
- *Klein: are the wind velocity and direction seasonal? [Hasselbach: In winter, from the NE, and the monument is relatively protected by small mountain. In summer, variable.]*

XII. Bill Manley demonstrated new technology and capacities in mapping.

After the presentations, April opened discussion for general comments or questions:

- *Hamilton: two general issues to discuss: training/education and helicopters. There's need for training and education in uniform, standardized protocols for data gathering and storage (from one park to the next and one generation to the next). We have lots of old photos and climate records. There are special attributes of arctic parklands, i.e., fragile tundra, permafrost, which will require training on site.*

Therefore we can integrate local communities into studies and monitoring, but education is key, from undergrad to K-12.

There are very different attitudes regarding helicopters in different parks. Must balance efficiency of access with disturbance: short-term noise vs long-term footprint. Sites will be disturbed in the future if too accessible by surface, and helicopters allow you to get to more remote/protected sites.

Diane Sanzone and Steve Young discussed previously drafted conceptual models.

Torre Jorgenson presented and discussed examples of models from previous workshops.

Bill Thompson presented and discussed the sample design development in the Southwest Alaska Network (SWAN).

April gave instructions before breaking into small working groups. She advised groups on how to revise or develop conceptual models, emphasizing the importance of outlining model content first. Each small group was assigned a facilitator from the ARCN Technical Committee.

- *Manley: are components and processes considered attributes? In the coastal workshop, each group had its own model. Is that appropriate, or should we aim for one unified model?*
- *Sanzone and Jorgeson: more specific is better, can be revised to become more general.*
- *Ring: what are we supposed to be revising?*
- *Sanzone: the models in your workbooks.*
- *Wesser: the exercise is intended to provide information for network selection of vital signs and to help define what we want to know about vital signs; it's not modeling for the sake of modeling.*

April explained that tomorrow's working group sessions will be used to develop questions based on the models, (i.e., what do we need to know about the ways these systems work?). Then we'll decide on highest priority questions, and there is often overlap among these questions. Diane urged participants to look at the results from the coastal resources workshop, in the notebook, for illustration of what we are after.

- *Ring: will there be chances to amend results after this?*
- *Sanzone: yes, it will be going out for review. Additions are welcome. There's also a fourth workshop.*
- *Liebscher: we need to keep process moving to produce deliverables, so it may not be perfect.*
- *Jorgenson: will there be another riparian wetlands workshop?*
- *Sanzone: originally, that area had its own workshop, as we worried about losing wetlands but finally it was included within coastal resources. Wetlands need to be kept in mind in this workshop; they are a huge piece of landscape.*
- *Jorgenson: personally thinks it should be incorporated rather than separated.*

Reports from First Working Group Session on Conceptual Models

I. Migratory and Invasive Species (Dave Payer reported for group)

- Basic ecosystem models vs. monitoring targets
- Structural vs. functional elements
- Biotic vs. abiotic factors
- Appreciated Owen Mason's model (p. 127 of workshop notebook; see overhead)
- Air-land-sea—structural and functional
- Native perspective, inputs from air to land
- Cites another model in workbook--???
- Element of time, changing relationships

(See Figure 1)

II. Land cover/land change (Torre Jorgenson presented for group)

- park-centric vs. terrain-centric
- offered several models:
  - *Hamilton: glaciated systems and deglaciation; sediment discharge, hydrography, landslides, disturbance; substrates of different ages, ecosystem development over time.* (See Figure 2.)
  - *Walker: mountains and bedrock, alpine slopes; carbonate/noncarbonate have different vegetation composition; snow accumulation, springs, hydrology, aufeis, groundwater movement, buried ice, nunataks. Topographic gradients affect shrub and poplar limits and foothills bedrock affect soils; permafrost degradation active layer.* (See Figure 3.)
  - *Manley: tundra lowlands, permafrost—thaw lakes, fire management leads to fires, then lichen, then reindeer and caribou; acidification.* (See Figure 4.)
  - *Young: boreal transition zones*
  - *Jorgenson, Janet: in Kobuk valley, periglacial sands and in lower Noatak, floodplains. Discharge, sedimentation, flooding, migrating channels, bank erosion, discontinuous permafrost, changes in temperature affecting decomposition, organic accumulation. Drivers: phenology, snow interception by spruce trees changing permafrost, species migration and exotics down river corridors.* (See Figure 5.)

III. Biodiversity (Kyle Joly presented for group)

- Group produced more than a species list, must be seen as living environment with genetic diversity. (See Figure 6.)
- Inventory vs. monitoring
- Used Chapin's model (from Diane's talk, not in notebook)
- Only one real driver; global change
- Factors included habitat, climate, perturbations, interspecies interactions, humans, time dimension

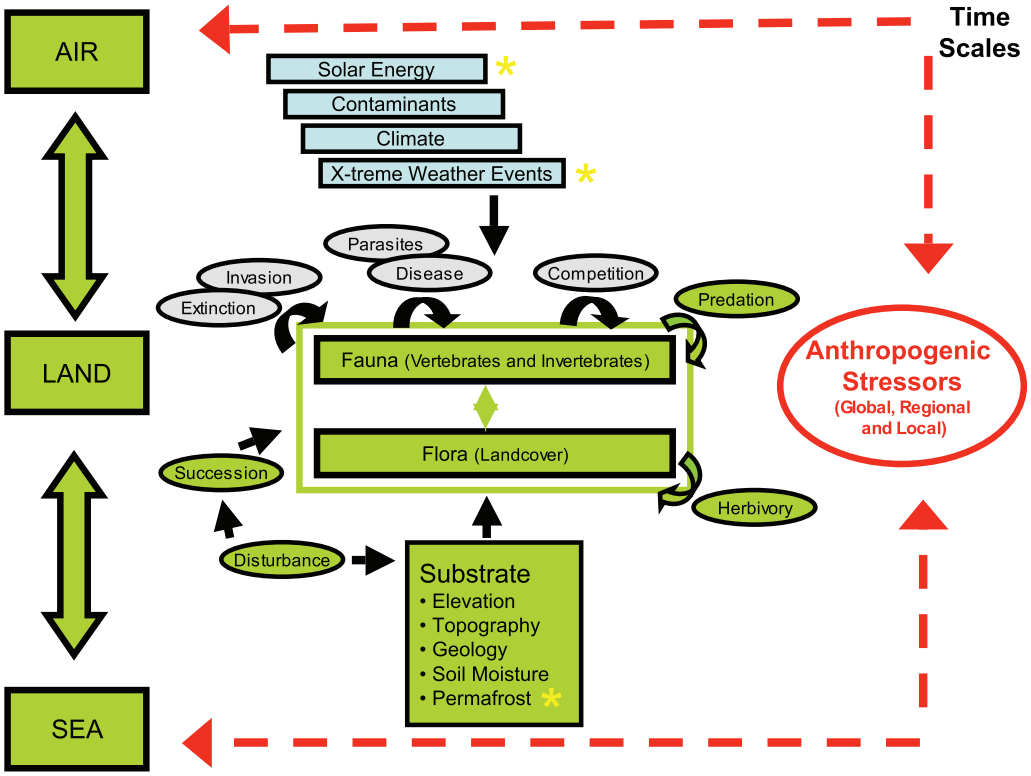


Figure 1

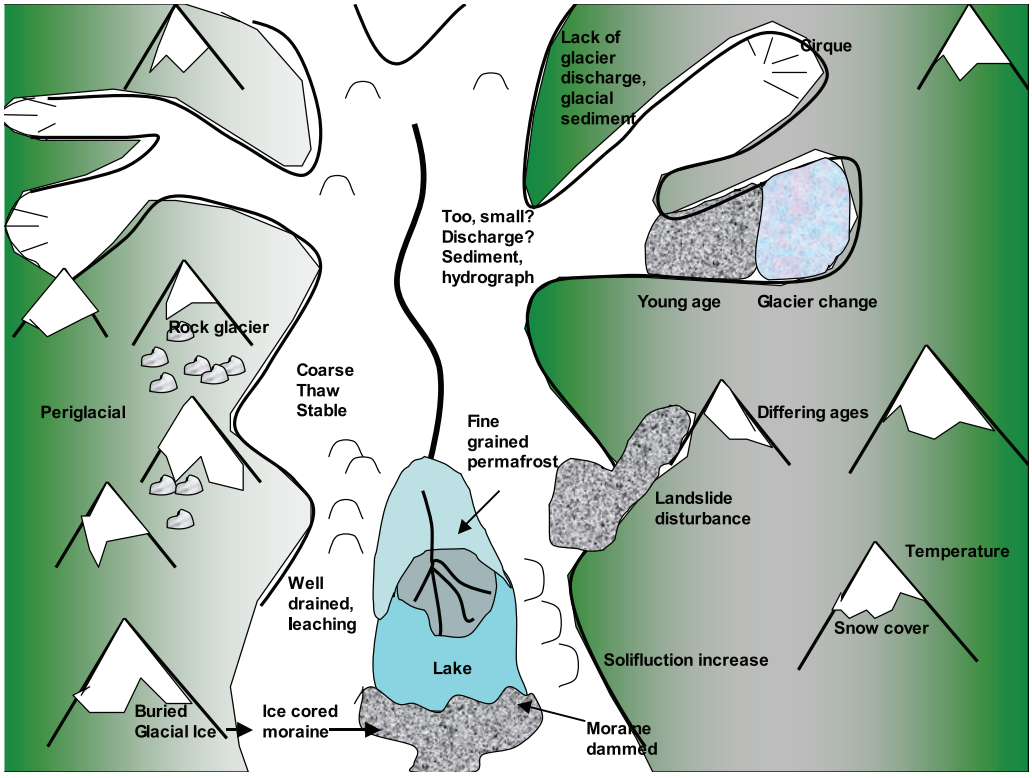
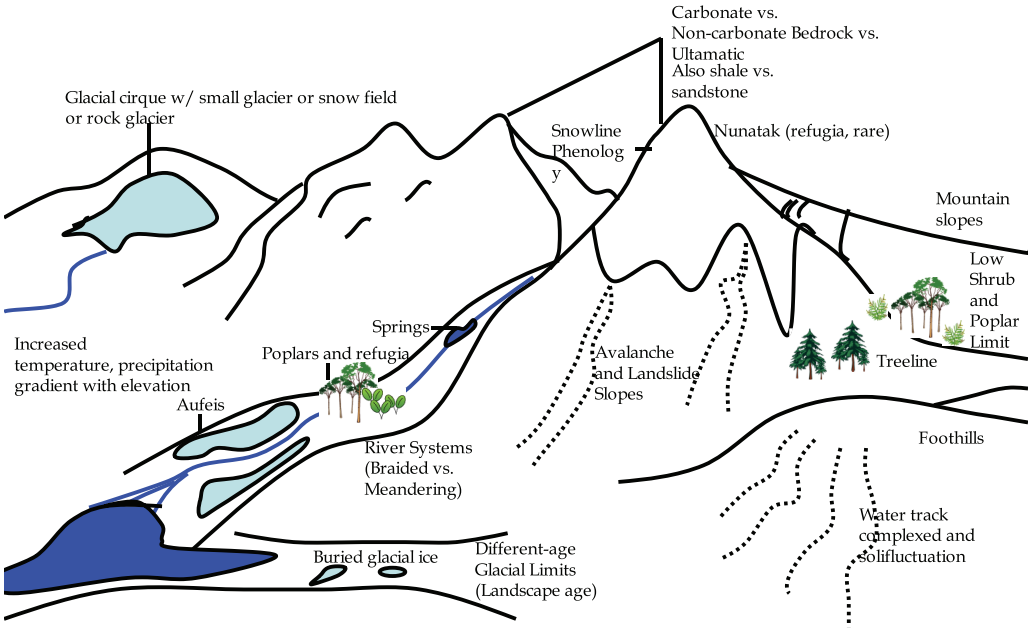


Figure 2



High vs. Low Ice Permafrost

Figure 3

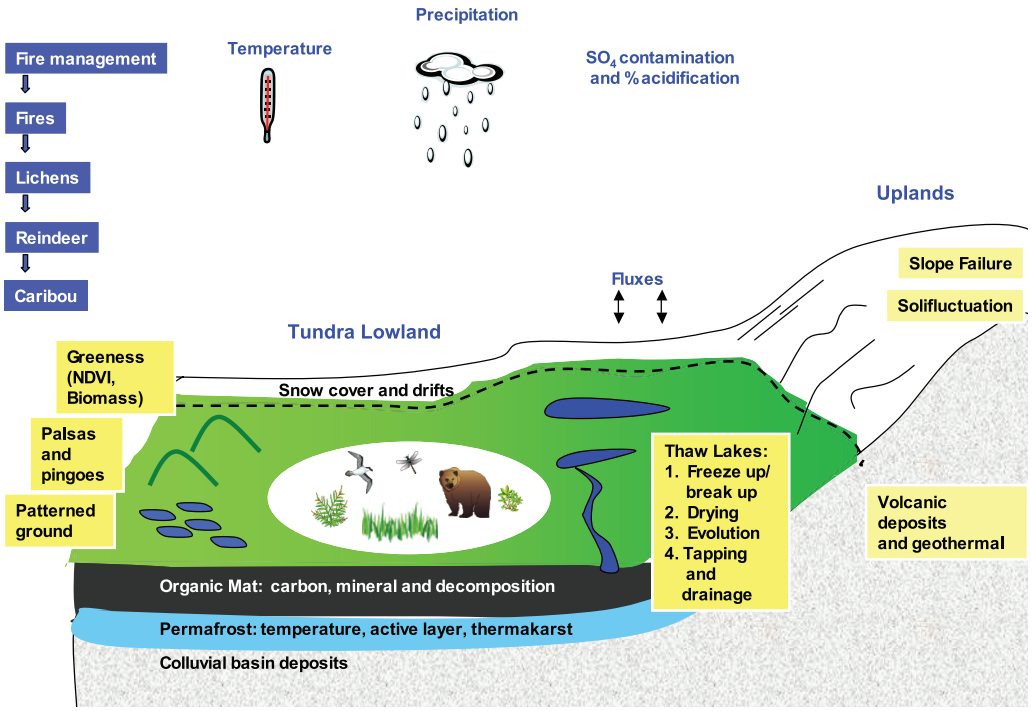


Figure 4

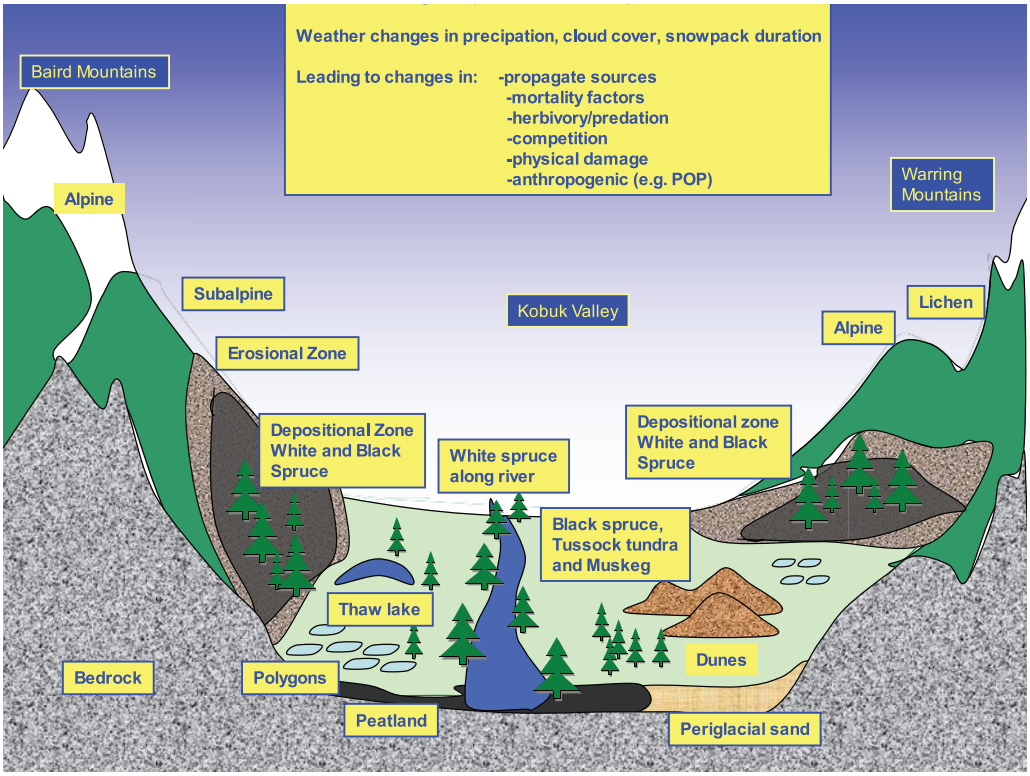


Figure 5

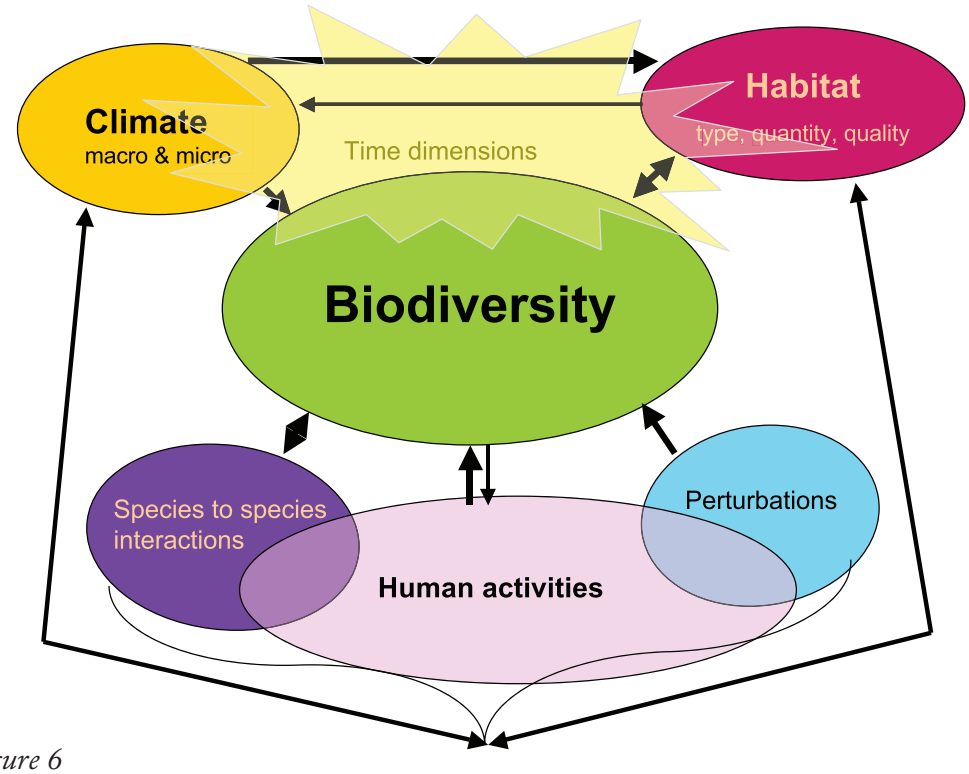


Figure 6

- Complexity accompanies surrounding drivers and stressors
- Weren't sure where to put humans; as part of perturbation, but also part of interspecific interactions—hunting vs. contaminants

Brian Barnes (continued presentation for biodiversity group):

- Seasonality
- Abundance and trends
- Health and physiological status
- Endangered habitats
- Abiotic drivers; i.e., length of growing season and conditions in winter—barriers to invasion that are now changing. (See Figure 7.)
- Phenologies: plants, animals, insects, diseases, etc., arrival, departure, green-up, peak, emergence
- Life history: clutch and litter size and timing, growth rates, dispersal, winter nutrition, life span
  - *Sanzone: perhaps can't predict for particular species, but can we make predictions for species assemblages under changing conditions?*
  - *Barnes: don't think so, need more info on particular organisms.*
  - *Klein: what about insects? Similar among particular family groups?*
  - *Ring: yes, could give examples where activity patterns depend on temperatures: the trigger to diapause is photoperiod, but trigger for emergence is conditions/temperature, so seasons would be advanced in beginning but not at end, i.e., wooly bear.*

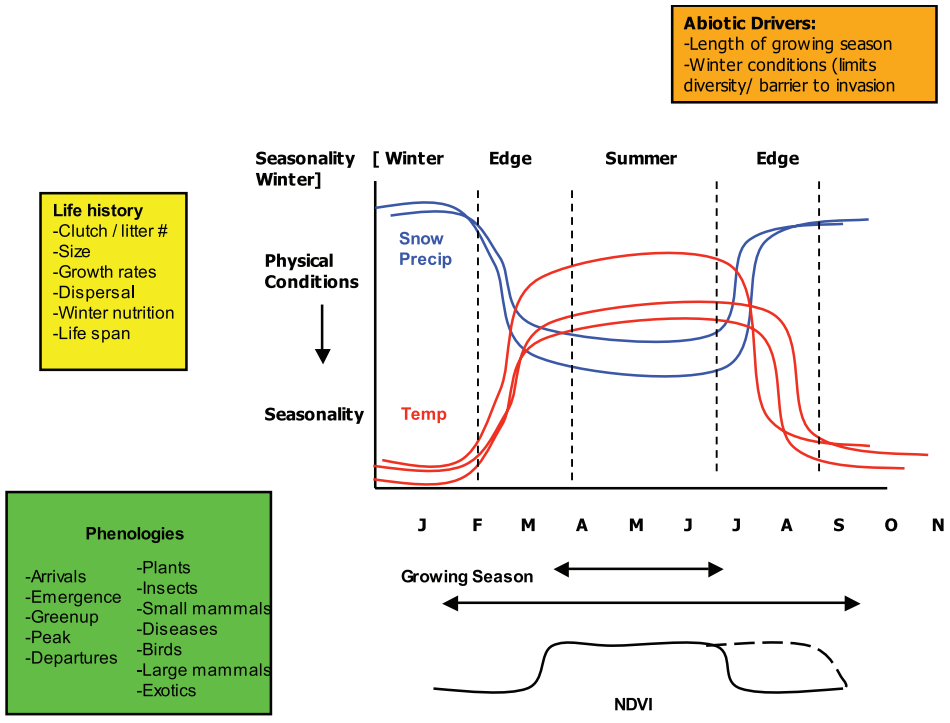


Figure 7

IV. Biogeochemistry (Roger Ruess presented for the group; also see overheads)

- Overwhelming topic; every aspect of biogeochemistry requires its own conceptual structure including landscape, topography, and hydrology.
- Addressed gradient of vegetation types (including wetlands), which are linked to one another through hydrological flow.
- Ecotonal boundaries are of particular interest for sampling, to make biogeochemical comparisons feasible. (See Figure 8.)
- Factors responding to as well as driving change include CNP (carbon, nitrogen, and phosphorus) cycling, net primary production (NPP), climate, water, gases, aerosols, climatic factors (See Figure 9.)
- Use remote sensing to look at soil moisture, snow cover, and other factors.
- List of threats: thermokarst release of old C (carbon) and nutrients, etc.
- Started on study design: vulnerable ecotones, latitude gradients, topographic transects, variables and processes (total soil CNP)
- Pools of available nutrients (extractable, resin bags)
- $\delta^{13}C$
- $\delta^{15}N$
- Soil C turnover: ^{14}C
- Decomposition of common litter substrate
- CN quality
- Thaw depth
- Vogel conceptual model (See Figure 10.)
- Climate change, thermokarst, invasive species, effects of soil C turnover

Following this presentation the following discussion occurred:

- *Hamilton: two of five parks have coastal areas, so do we need to review results of coastal workshop?*
- *Sanzone: question of coastal definition; fairly restricted, so, yes, please take a look at it.*
- *Klein: what about estuarine?*
- *Answer: It's in the workbook.*

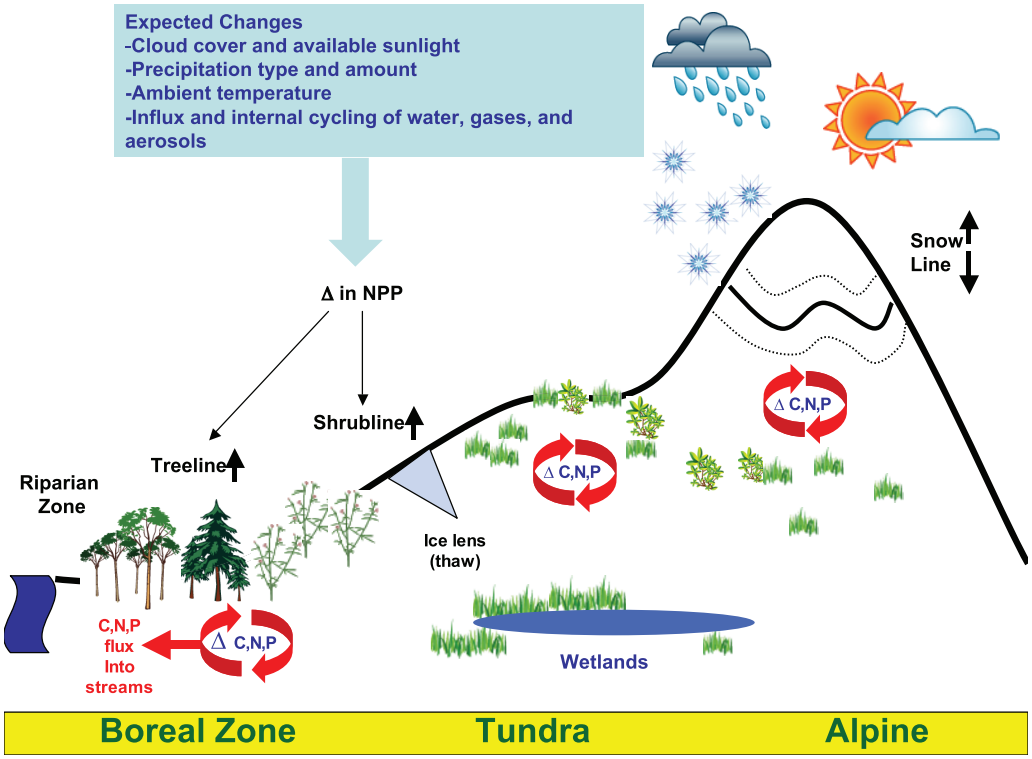


Figure 8

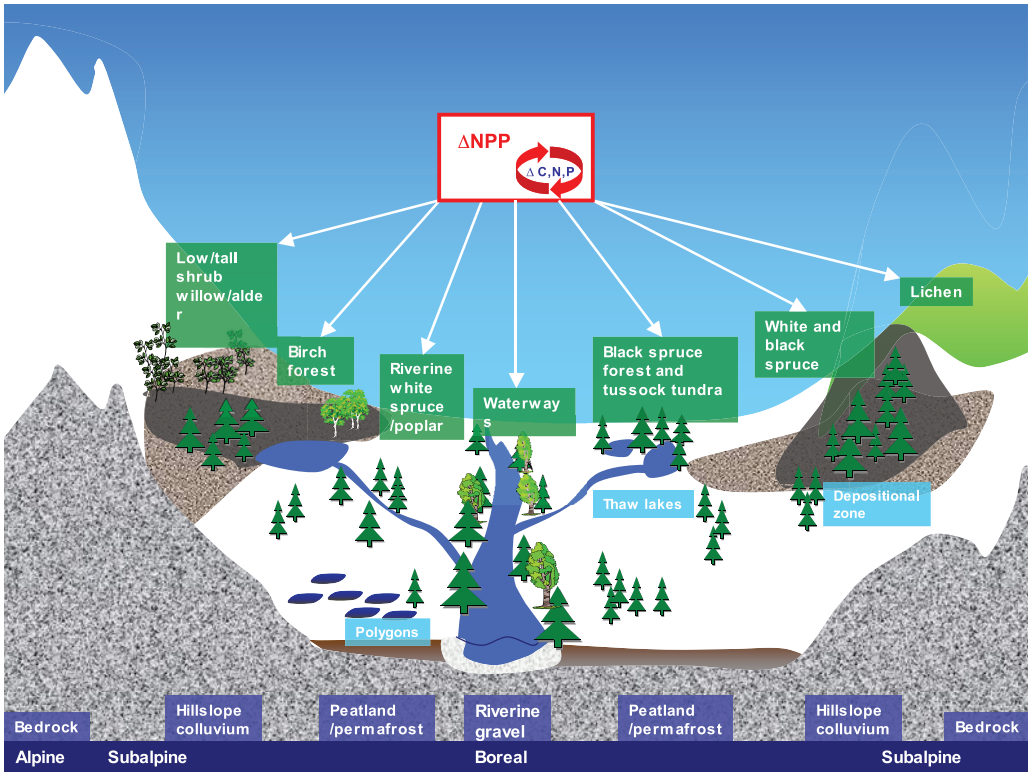


Figure 9

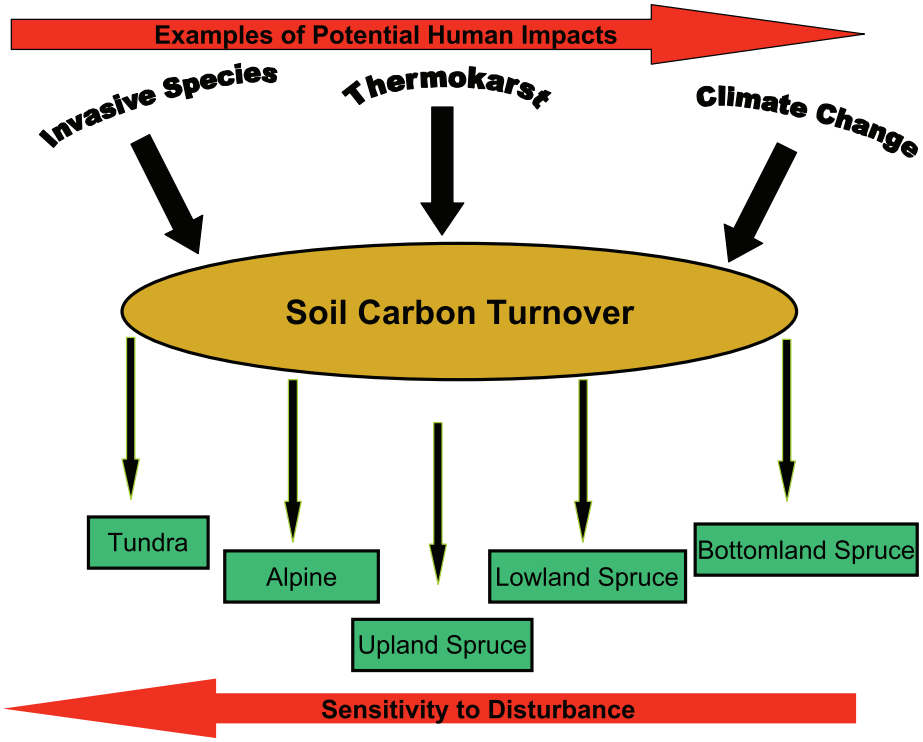


Figure 10

Day 3: Thursday April 28, 2005

The day started with instructions to the working groups for them to develop their lists of potential monitoring questions. Use of the database to record these questions was also explained. After a two-hour work session, the groups reported back, using the database.

Biogeochemistry (Roger Ruess): in database

Biodiversity (Brian Barnes): not in database, see word file

Landcover/Land Change (Bill Manley): in database

- *Sanzone: number of glaciers in Brooks Range?*
- *Manley: maybe about 500, has done some cataloging.*

Migratory/Invasive Species (Steve Arthur):

- There are two major questions: migration and invasives, details forthcoming.
  - *Jorgeson: what of shifts in ranges of other species, neither invasive or migratory, i.e., example, ravens, moose*
  - *Arthur: haven't thought about it; the question may overlap with biodiversity group*
  - *Ruess: what about interspecific interactions?*
  - *Arthur: haven't thought about it.*

Following review of the working group efforts, April opened discussion for general comments of questions.

- *Thompson: there seem to be six or seven high-priority questions shared by same group. Did you expect overlap in topics?*
- *Sanzone: yes, not sticking exactly to five questions; also there are lumpers vs splitters*
- *Hamilton: how many votes do we each get?*
- *Manley: what is vital sign vs. attribute?*
- *Sanzone: vital signs are largely components/processes/attributes of a system.*
- *Wesser: can think of them as an "indicator" in monitoring, or can also be something that matters to managers, mentioned in enabling legislation*
- *Sanzone: there is a definition on page 106 of the workshop notebook.*
- *Payer: what is the desired degree of specificity?*
- *Sanzone: we can use some additional detail in conceptual models*
- *Crosby: also we need to capture unique features of parks*
- *Matheus: some of the categories are easier to write questions for and others easier to make statements, so is it OK if it is not in form of question?*
- *Sanzone: yes, you may add comments.*
- *Wesser: What about rare species—are they included in biodiversity? Migrating vs. invasive species?*
- *Sanzone: we're following NEON's lead on this. Why did NEON have a group on migrating and invasive species?*
- *Bret-Harte: The impact is greater of invasive species in Lower 48, so it's a big issue for NEON.*
- *Liebscher: we need to keep track of the deliberations and discussions, there's lots of information that will be used in the development of program; one group has list of rare species to keep in mind.*

The next topic was instruction for the final working group assignment and the task of selecting top priority questions. Discussion of the task included:

- *Lawler: are we looking for candidates for monitoring, specifics?*
- *Klein: or are we monitoring systems?*
- *April: it's partly a balancing act.*
- *Sanzone: for example, dunes as rare community, so they could be a component by themselves.*
- *Manley: is part of this exercise deciding on criteria for good questions?*
- *April: criteria for the questions are on page 56 of the workshop notebook.*
- *Matheus: What is the NPS position on monitoring components of important systems that occur outside of park, for example, caribou calving outside park?*
- *Larsen: go ahead and mention it, but may need to find appropriate partner to do work.*

- *Liebscher: jurisdictional boundaries should not be a big deal, look at page 56 in the notebook—it's all one system.*

Following the final working group exercise, groups taped their questions together on the walls for review by all. Then each group read out its priority questions. (See list of proposed questions.) Discussion followed regarding what votes meant and how to best vote.

- *Question: consider the example of a fire question. Do we vote for this because it is important, even though another agency does it?*
- *Allen: it is still a priority; but true, it will happen anyway.*
- *Liebscher: the interagency fire program will do it.*
- *Klein: if we don't partition the questions, will you guys separate them later?*
- *Thompson: SWAN includes much information collected by other agencies. The I&M program fills gaps, but don't exclude something just because other agencies do it.*
- *Question: do we vote for what is important or where we think the money should go?*
- *Sanzone: Vote for what is important.*

After the voting, we put questions with the highest number of votes together, gathered the questions with middling-votes together, and established a third group that had a small number of votes. Discussion followed regarding whether there was overlap among the questions and whether some of them could be lumped together. Several questions about permafrost were put together, and several about anthropogenic changes were put together.

Next, Diane Sanzone displayed some of the draft models developed from the small group work the previous day. After some discussion, April proposed we wrap up by opening discussion for general comments of advice to the ARCN staff as they go forward. For example, participants might look for what, if anything is missing from the discussion of monitoring so far?

- *Janet Jorgenson: we are missing part of park mandates; subsistence values and wilderness values (especially for GAAR, i.e., noise monitoring).*
- *Matheus: we assume you're not using this material verbatim. How will you take charge of it?*
- *Sanzone: we will edit and send it out for review at several stages.*
- *Allen: the landcover/land change group lumped some stuff and I don't think it got into the database.*
- *Hamilton: we boiled down 25 questions, and some elements got submerged; for instance, unique resources (i.e., paleo-material, bone beds), things that are disappearing (organic record).*
- *Ruess: subsumed details of biogeochemistry may be relevant to biodiversity issues, so step back to details.*
- *Jorgeson: attributes and things to measure seem to have gotten lost, so should we take time now?*
- *Klein: there is an ecosytems bias. What about subsistence use? Humans as stressors and drivers get forgotten except as pollutants. Can you monitor the attitude of humans to land? Has that changed over time? Human attitudes about wilderness, about conservation?*

- *Olson: we have proposed here the largest LTER project in world! You will have to consolidate logistics where possible.*
- *April: there is a collaborator/cooperator column on the database set up to get your recommendations about who is helpful in any given area. This group didn't really get to it, but it is a big focus; to be efficient and cost-effective.*
- *Payer: it's not an LTER, it is monitoring. What about drawing inferences about causation and developing prediction. Diane, comment on expectations?*
- *Sanzone: I think research and monitoring can be closely related.*
- *Young: there's no limit to time over which this can be valuable. Baseline data.*

After this discussion, April asked for discussion of the workshop process.

- *Allen: the presentations very beneficial*
- *Thompson: will the presentations be posted somewhere?*
- *Scott: yes, they will be on the ARCN website.*
- *Klein: it would have helped the value of the presentations to have more time for questions.*
- *Wesser: Lois and Brad's talk was good; I'd suggest more information on managers' perspective, perhaps a panel discussion?*
- *Ruess: where do you go from here and how are you going to do this work?*
- *Diane: ARCN is short staffed, so 99% done by cooperators, contractors, etc.*
- *Bret-Harte: we got great questions, now need to design strategy for sampling. Do you need help from scientific community?*
- *Diane: a workshop after the Phase 1 report will work on this issue; and we have the models of CAKN and SWAN.*
- *Lois: from a perspective of long service in NPS, this process would not have happened 30 years ago. We should be pleased by progress.*
- *Tom Heinlein: I'd like to echo Sara's suggestion for a panel of managers' perspectives, and also echo Lois's appreciation for real progress in NPS.*

Thanks to everyone involved.